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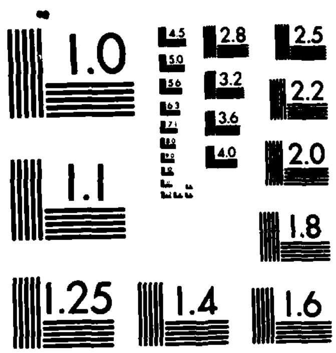
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REPORT NO. T10/85

AN AUTOMATED SYSTEM FOR COMPREHENSIVE ASSESSMENT OF VISUAL FIELD SENSITIVITY

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

APRIL 1985

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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This report describes a device for comprehensive assessment of the capability of operators for detection and location of visual signals throughout the functional visual field. The system is completely automated and computerized, and provides documentation files and graphic descriptions of each operator performance immediately upon completion of testing. Sensitivity can be measured for three stimulus colors (red, yellow, green), in a testing situation which mimics commonplace viewing. An abbreviated listing of the main operating program software is provided. Keywords: visual perception.

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An Automated System for Comprehensive Assessment of Visual Field Sensitivity

John L. Kobrick, Adrien R. Lussier, Stephen Mullen and Calvin Witt

US Army Research Institute of Environmental Medicine

FOREWORD

This device was developed collaboratively among the authors to support the research of the senior author on effects of environmental stress and the wearing of standard Army headgear systems on functional viewing. The original measurement system was developed over the course of several previous studies, and was based on manual operation techniques. The software involved in a later computerized version described in this report was largely the creation of SFC Adrien Lussier, who is to be commended for his imagination and creativity, and without whose efforts this system would not have been completed. Mr. Stephen Mullen and SP6 Calvin Witt are also to be commended for their creativity and originality in design of the hardware aspects of the system.

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Figure 2. Schematic diagram of control system lash-up

ABSTRACT

This report describes a device for comprehensive assessment of the capability of operators for detection and location of visual signals throughout the functional visual field. The system is completely automated and computerized, and provides documentation files and graphic descriptions of each operator performance immediately upon completion of testing. Sensitivity can be measured for three stimulus colors (red, yellow, green), in a testing situation which mimics commonplace viewing. An abbreviated listing of the main operating program software is provided.

INTRODUCTION

An important aspect of general vision is the ability to detect stimuli occurring in the peripheral areas of the visual field. The fovea clearly is the locus of greatest sensitivity under photopic viewing conditions, but detection capability is present also to varying degrees in virtually all areas of the visual field. It has been shown that the zone of greatest overall detection sensitivity encompasses an area distributed along the horizontal axis in an ovaloid configuration (Kobrick, 1965). Sensitivity diminishes progressively at greater eccentricities, with the greatest losses occuring in the superior and inferior zones due to obstruction of the visual field by the nose and forehead (Kobrick, 1971, 1972, 1974, 1975; Kobrick and Appleton, 1971; Kobrick and Dusek, 1970; Kobrick and Sutton,1970).

A variety of conditions can act to degrade this basic configuration; e.g., pathology, such as glaucoma and retinitis pigmentosa; environmental extremes, such as hypoxia; atmospheric pollution, such as carbon monoxide. For these and other practical reasons, therefore, it is essential to be able to document accurately the relative sensitivity levels for stimulus detection throughout the entire visual field, and a variety of perimeters have been developed for this purpose (e.g., Goldmann, Harms, Aimark, Bausch & Lomb).

Although clinical perimeters provide accurate and reproducible data when properly used, they all suffer from a limitation of realism in the visual task required. Since the majority of these devices employ a rotatable axis for stimulus presentation, they intrinsically provide a cue for location of the stimulus. The clinical measurement procedure itself is an even more general source of location cueing, which further distorts the subject's "natural" response by compartmentalizing the performance into a series of discrete responses to individual hemispheric axes. Thus, although these instruments can provide an accurate picture of the absolute limit contours of the sensate visual field, they fail to mimic the overall continuous nature of commonplace viewing, and are unable by design to assess detection sensitivity throughout the visual field area in an ongoing functional manner resembling normal vision.

The instrument described here is an automated programmable system for continuously assessing relative stimulus detection sensitivity over a variety of locations distributed throughout the visual field. This device avoids the problems of measurement bias inherent in other perimeters by presenting the stimulus for detection in an unpredictable pattern of temporal occurrence and location. The subject's detection efficiency is judged on the basis of his response time for signal detection, a measure of performance which quickly becomes asymptotic and remains relatively unchanged thereafter.

DESCRIPTION OF HARDWARE

The stimulus configuration consists of 32 units of 3 6VDC light-emitting diodes (LED's) each, distributed about the visual field of the subject. Each unit consists of one 1/8 inch diameter circular red, yellow and green LED, respectively, spaced 1/4 inch apart and mounted on a small metal template. Given the appropriate control programming, this feature allows the option of testing red, green or yellow sensitivity either as separate administrations or interleaved in any desired pattern. The LED units are mounted on a hemispherically-shaped ribbed structure. (See Figure 1.)

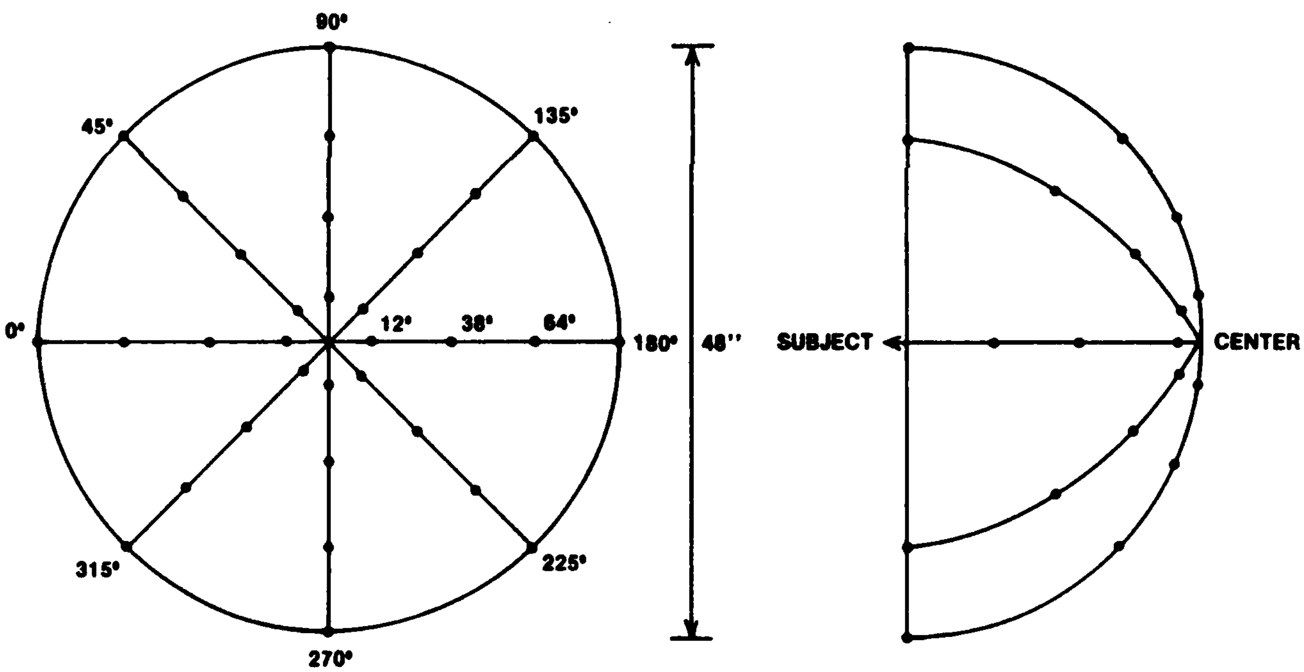

Figure 1. Schematic diagram of the visual testing system

This hemisphere is constructed of 3/32 inch x 3/4 inch curved aluminum strips, each joined at one end to an 8-inch diameter circular center-plate at equal intervals around its edge, and connected sequentially at the other end by 19-inch spacing rods. This arrangement results in a structure composed of eight curved ribs spaced at 45-degree intervals to form a 48-inch diameter hemisphere. The interior surfaces of the ribs are faced with the black pile membrane of hook-and-pile fastener material (Velcro), and a tab of the accompanying hooked membrane is cemented to the back of each LED template, so that the stimulus lights can be conveniently adhered anywhere along the ribs of the hemisphere. In the research in which the apparatus has currently been employed, the LED units were positioned on each of the eight ribs at 12°, 38°, 64° and 90° angular displacement from the center of the hemisphere. However, the Velcro feature allows the positioning of the LED stimuli in any desired arrangement. It should also be noted that the common radius of the hemispheric rib structure provides that the stimulus lights are all at the same distance from the viewing position, and thus subtend the same visual angle.

All metal surfaces of the rib structure are painted flat black, and the back side of the entire assembly is enclosed in a matte black fabric cover. The center plate of the hemisphere is mounted by a sliding clamp to a vertical pipe to allow adjustment of viewing height to the subject's seated position.

The subject is seated in a contoured seat with an adjustable headrest. (A salvaged Volkswagen front bucket seat with an adjustable reclining control was found to be cheap and effective.) The seat is positioned so that the subject's line of sight intersects the center of the hemisphere, and the edge of the hemisphere abuts the peripheral limit (90°) of the visual field.

The entire task is generated and administered by a Hewlett-Packard HP-87XM computer and an associated H-P Model 82901M dual floppy-disk drive. The following HP ROM's are also required: I/O; Plotter; Advanced Programming; Matrix; and, 256 Kbytes Memory. This system is configured in turn with two H-P Model 3495A scanners, each with three 20-channel low thermal relays and one 10-channel relay actuator. These latter units generate the necessary switch closures for LED activation. Additional devices used in the present assembly include an H-P Model 59313A A/D converter, and an H-P Model 9871A character impact printer. A schematic diagram of this equipment lash-up is shown in Figure 2.

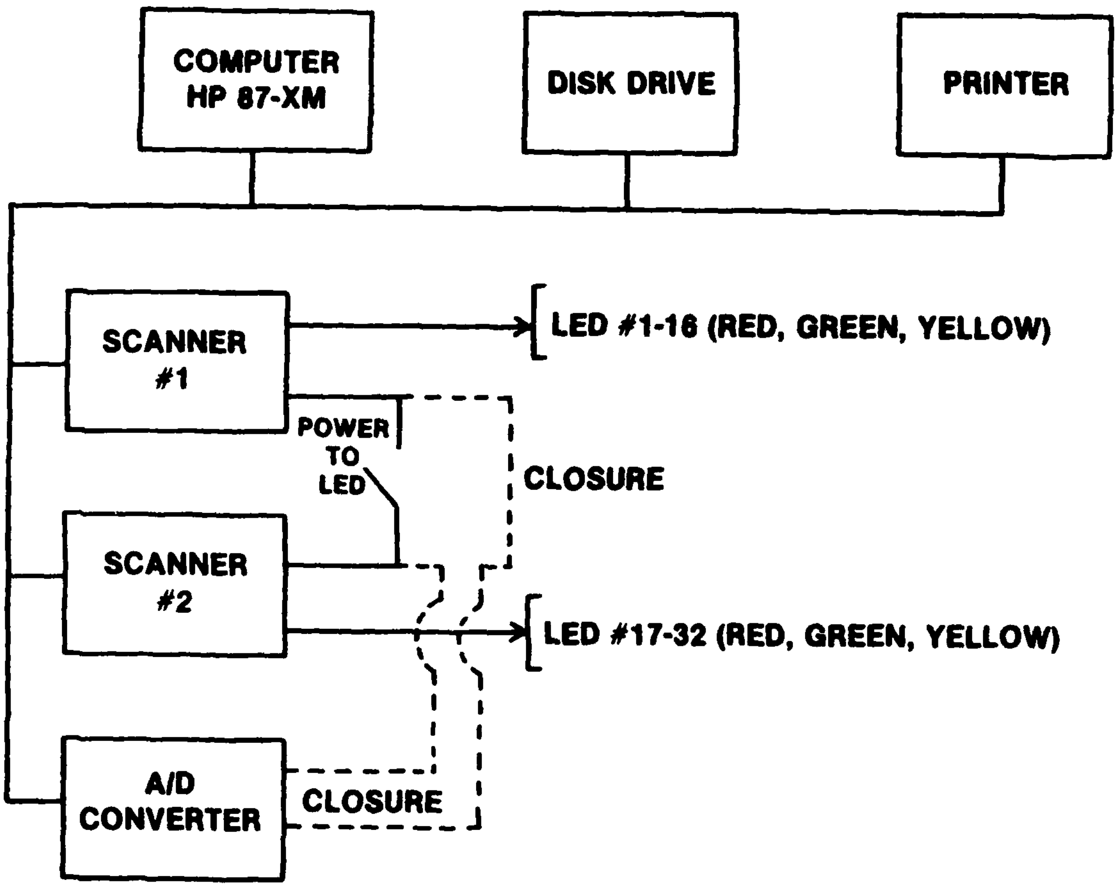

Figure 2. Schematic diagram of the equipment system lash-up

OPERATING PROCEDURE AND SOFTWARE

The subject's task is to orient his line of sight toward the center of the display, and to monitor the entire visual area for activations of any of the LED's. He is trained to respond to any detection by pressing a push-button switch held in the preferred hand. The system measures and stores the response time interval (RT) in milliseconds following each LED activation to the point of switch closure. Thus, RT for signal detection is the basic measure employed by this system as an index of relative visual field sensitivity. As presently programmed, the system presents all lights of the specified class (red, green, yellow or their combinations) in randomized order of occurrence, with the provision that no light is repeated until all of the specified class have occurred. The lights are presented at randomized intervals ranging in value between 5 and 20 seconds following switch closure of the previous detection. Signals which are not detected within 5 seconds are considered to be missed, and the system then arbitrarily assigns them that RT value, which is a virtually infinite

magnitude in the realm of response time or reaction time behavior, and, therefore, a missed signal. In practice, the RT has proven to be a good measure to represent relative visual detection capability, because the task is acquired quickly, remains asymptotic once training is complete, and appears to be sensitive to exposure to environmental and other stressors.

As presently configured, all system software is programmed in BASIC. A complete copy of the software can be obtained by contacting the authors.

After boot-up and initialization, the program prompts for insertion of system and data disks and checks for correct insertion. It then prompts for calibration of the A/D converter and for initiation of output devices (printer or other accessories). (A/D calibration is recommended at least once daily, or every four hours when the system is used continuously.) Prompts are then given for identification of the test conditions, stimulus characteristics, and historical documentation of the test run and research study involved. The system then requests identification of the test subject (name, social security number, optional information) and identification of the technician. All instructions thereafter are user-friendly, in that the technician is referred to by name. The program includes numerous reminders and helpful prompts to assist in operation of the equipment. Key-stroke sub-routines are also provided for performing system checks of the stimulus lights, in which all lights flash individually in sequence.

In its present form, the program provides a READY prompt, and when given a RUN command, conducts the entire testing procedure according to the stimulus and test parameters specified at the beginning of the procedure. Instructions are provided to the subject automatically through a voice synthesizer at the appropriate points in conduct of the test. Upon completion of the testing procedure, the system stores the RT data and provides a printed listing of the relevant test information, and the RT values listed against the stimulus characteristics and visual field locations. Finally, the system prints two graphic representations of the averaged RT's, one for RT versus the degree of peripheral stimulus location, and the other for RT versus radial position of stimuli in the visual field.

ABBREVIATED PROGRAM

An abbreviated version of the main operating program of this system is as follows.

```
10 ! PERIPHERAL VISION TESTING SYSTEM
20 ! USARIEM, HEALTH & PERFORMANCE DIVISION
30 !     by SFC AR LUSSIER -- VERSION 3.03 -- DECEMBER 1983
40 !
50 !
3010 ! ===================* LIGHTS/COLOR SECTION *=================
3020 ! ==============================================================
3021 !
3022 ! This section prepares the light sequences for presentation
3023 ! ----- User selection of light stimuli -----
3024 !
```

```
3030 OFF CURSOR @ ALPHA SCREEN @ FOR A=1 TO 10 @ DISP @ NEXT A @ OFF CURSOR
@ ALPHA SCREEN @ DISP "LIGHT Information"
3040 FOR A=1 TO 3 @ ON A  GOSUB Red ,Green ,Yellow  @ DISP USING "4X,D,X,K"
; A,"= "&Temp1$ @ NEXT A
3050 DISP TAB (5);"R = Random selection  of color(s)" @ DISP TAB (3);"Rxx =
Random order of any two specified colors"
3060 L1=1 @ Prompt$="Number of colors to be processed" @ GOSUB Question
3070 IF LEN (Ans$)#1  OR  Ans$[1,1]<"0"  OR Ans$[1,1]>"3" THEN DISP "Please
enter a number within the range of 1  to  3" @ OFF CURSOR @ ALPHA I2 @ GOTO
3060
3080 IF Stdtype$="CD" THEN Color=1 ELSE Color=VAL (Ans$)
3090 IF Stdtype$="PV" THEN 3120
3100 OFF CURSOR @ ALPHA  I2+2  @  DISP  @  OFF  CURSOR  @ ALPHA I2 @ L1=1 @
Prompt$="Primary color.  If you  have  no  preference  type in 'R'" @ GOSUB
Question
3110 GOTO 3130
3120 OFF CURSOR @ ALPHA  I2+2  @  DISP  @  OFF  CURSOR  @ ALPHA I2 @ L1=4 @
Prompt$="Color order.  If  you  have  no  preference  type  in 'R'" @ GOSUB
Question
3130 IF LEN (Ans$)>4 THEN OFF CURSOR @ ALPHA I2 @ GOTO 3090
3140 Order$=UPC$ (Ans$) @ IF POS (Order$,"R")=0 AND LEN (Order$)>Color THEN
OFF CURSOR @ ALPHA I2 @ GOTO 3090
3150 IF  POS  (Order$,"R")#0  OR  Color=1  AND  POS  (Order$,"R")=0 AND LEN
(Order$)=1 THEN Ans$="N" @ GOTO 3180
3160 L1=1 @ Prompt$="Repeat the sequence  of  lights?   Y/N" @ OFF CURSOR @
ALPHA I2 @ GOSUB Question
3170  IF  LEN  (Ans$)=1   AND   (POS   (UPC$  (Ans$),"Y")=0  OR  POS  (UPC$
(Ans$),"N")=0) THEN 3180 ELSE OFF CURSOR @ ALPHA I2 @ GOTO 3160
3180 Rep$=UPC$ (Ans$) @ OFF CURSOR @  ALPHA  I2 @ DISP @ DISP HGL$ ("Please
be patient while I try to generate some random numbers!") @ OFF CURSOR
3190 IF Stdtype$="CD" THEN GOTO 5000
3191 !
4000 ! ===========*  RANDOM PROCESS  VISUAL PERCEPTION  *============
4010 ! ==============================================================
4011 !
4020 RANDOMIZE DATE *TIME  @ Lights$,Delay$="" @ IF POS (Rep$,"Y")#0 OR POS
(Order$,"R")=0 THEN Color1=1 ELSE Color1=Color
4030 Temp2$,Temp3$="" @ FOR A=1 TO 32*Color1
4040 Colors$=CHR$ (INT (RND *32*Color1)+1) @ IF POS (Temp2$,Colors$)#0 THEN
4040 ELSE Temp2$=Temp2$&Colors$ @ Temp3$=Temp3$&CHR$ (INT (RND *10)+1)
4050 NEXT  A  @  IF  POS  (Rep$,"Y")#0  THEN  Lights$=RPT$ (Temp2$,Color) @
Delay$=RPT$ (Temp3$,Color) @ GOTO 4080
4060  IF  POS  (Order$,"R")=0  AND  LEN  (Lights$&Temp2$)/32=Color  OR  POS
(Order$,"R")#0 THEN 4070 ELSE Lights$=Lights$&Temp2$ @ Delay$=Delay$&Temp3$
@ GOTO 4030
4070 Lights$=Lights$&Temp2$ @ Delay$=Delay$&Temp3$
4080 FOR A=1 TO LEN (Lights$)
4090 IF NUM  (Lights$[A,A])>32  THEN Lights$[A,A]=CHR$ (NUM (Lights$[A,A])-
32) @ GOTO 4090
```

```
4100 NEXT A @ Colors$="" @ MAT Results=ZER @ IF POS (Order$,"R")#0 THEN
4120
4110 FOR A=1 TO Color @ Colors$=Colors$&RPT$ (Order$[A,A],32) @ NEXT A @
GOTO 6010
4120 Temp2$,Temp3$="" @ IF Color=1 THEN Order$=VAL$ (INT (RND *3)+1) @ GOTO
4110
4130 IF LEN (Order$)#1 THEN 4170
4140 FOR A=1 TO Color
4150 Temp3$=VAL$ (INT (RND *3)+1) @ IF POS (Temp2$,Temp3$)=0 THEN
Temp2$=Temp2$&Temp3$ ELSE GOTO 4150
4160 NEXT A @ Order$="R"&Temp2$
4170 Order$=ROTATE$ (Order$,LEN (Order$)-POS (Order$,"R")+1)
4180 A=6 @ FOR B=2 TO LEN (Order$) @ A=A-VAL (Order$[B,B]) @ NEXT B @ IF
A=0 THEN 4200
4190 FOR B=0 TO 32 @ Results(A,B)=1 @ NEXT B
4200 FOR A=1 TO LEN (Lights$)
4210 B=INT (RND *3)+1 @ IF Results(B,NUM (Lights$[A]))=1 THEN 4210 ELSE
Colors$[A,A]=VAL$ (B) @ Results(B,NUM (Lights$[A]))=1
4220 NEXT A @ GOTO 6010
4221 !
5000 ! ========* RANDOM PROCESS COLOR DISCRIMINATION *============
5010 ! ============================================================
5011 !
5020 IF Order$="R" THEN Order$=VAL$ (INT (RND *3)+1)
5030 Temp1$,Temp2$="" @ FOR A=1 TO 32
5040 Temp1$=CHR$ (INT (RND *32)+1) @ IF POS (Temp2$,Temp1$) THEN 5040 ELSE
Temp2$=Temp2$&Temp1$
5050 NEXT A @ Lights$=""
5060 B=1 @ FOR A=1 TO 32 @ Temp=INT (RND *3)
5070 Lights$[B]=RPT$ ("|",Temp)&Temp2$[A,A] @ Colors$[B]=RPT$
("0",Temp)&Order$
5080 B=B+Temp+1 @ NEXT A @ B=B-1
5090 Delay$="" @ FOR A=1 TO B @ Delay$=Delay$&CHR$ (INT (RND *10)+1) @ NEXT
A
5100 C=3*LEN (Delay$) @ Lights$=Lights$[1,B]&RPT$ ("|",C-B) @
Colors$=Colors$[1,B]&RPT$ ("0",C-B)
5110 Temp1$,Temp2$="" @ C=B @ FOR A=1 TO LEN (Delay$)
5120 Temp=INT (RND *3) @ IF Temp=0 AND NUM (Lights$[A,A])=0 THEN 5120
5130 IF Temp#0 THEN 5140 ELSE Lights$[C+A,C+A],Lights$[C*2+A,C*2+A]="|" @
Colors$[C+A,C+A],Colors$[C*2+A,C*2+A]="0" @ GOTO 5170
5140 FOR B=1 TO Temp @ Temp1$=CHR$ (INT (RND *32)+1)
5150 Temp2$=VAL$ (INT (RND *3)+1) @ IF POS (Colors$[1,C],Temp2$)#0 OR
Colors$[C+A,C+A]=Temp2$ THEN 5150
5160 Lights$[C*B+A,C*B+A]=Temp1$ @ Colors$[C*B+A,C*B+A]=Temp2$ @ NEXT B
5170 NEXT A
5180
 "
10000 ! ============================================================
10001 !
```

```
10010 ! DATA COLLECTION
10020 ! SECTION #1 ** SET-UP
10021 !
10030 ! ================================================================
10040 REDIM Results(0,LEN (Delay$))@ FOR RUNS=SUBJ+1 TO SUBJ+Subnum ! OUTER
SUBJECT LOOP
10050 PAGESIZE 16 @ ON KEY# 1,"START" GOTO 10110 @ OFF KEY# 2 @ OFF KEY# 8
10060 CLEAR @ MAT Results=ZER @ DISP "Subject #"&VAL$ (RUNS-SUBJ)&" is
"&NAME$(RUNS) @ DISP
10070 L1=32 @ Prompt$="Any special comment to be made? (If none type in
NONE)" @ GOSUB Question
10080 IF UPC$ (Ans$)="NONE" THEN CMT$(RUNS)="" ELSE CMT$(RUNS)=Ans$
10090 CLEAR @ KEY LABEL @ DISP "Press "&HGL$ ("KEY #1")&" to start." @ DISP
@ DISP "Subject:  "&HGL$ (NAME$(RUNS)) @ OFF CURSOR
10100 GOTO 10100
10110 ALPHALL @ ALPHA @ ON KEY# 8,"ABORT" GOTO Abort  @ ON KEY# 1,"RESTART"
GOTO Restart
10120 Temp1$="Subject$:  "&HGL$  (NAME$(RUNS))  @  OFF CURSOR @ ALPHA 1,INT
((80-LEN (Temp1$))/2) @ AWRIT Temp1$
10130 !
10140 ALPHA 2,18 @ AWRIT "Seq#  Light  Color   Delay   Reaction   Mean"
10150 RESTORE 10160 @ FOR C=8 TO  16  @ READ Temp1$,X@ ALPHA C,32+X @ AWRIT
Temp1$ @ NEXT C
10160 DATA ! CONTAINS ASCII CODES FOR LIGHTS
10170 DATA ! CONTAINS ASCII CODES FOR LIGHTS
10180 DATA ! CONTAINS ASCII CODES FOR LIGHTS
10190 ALPHA 15,1 @  AWRIT  HGL$  ("  ABORT  ")  @  ALPHA  16,1 @ AWRIT HGL$
("RESTART") @ ALPHA 1,1 @ ON CURSOR
10191 !
11000 ! SECTION #2 ** INFORMATION DISPLAY
11010 ! ==============================================================
11011 !
11020  MAT  Results=ZER  @   Smean,Snum=0  @  Tmm$(RUNS)=TIME$     @
Tmm$(RUNS)=Tmm$(RUNS)[1,5] @ FOR B=1 TO LEN  (Delay$)  @ Buf$="" @ ON EOT 7
GOTO 12050
11030 I2=4 @ FOR C=4 TO 6 @ OFF CURSOR @ ALPHA C @ DISP @ NEXT C
11040 FOR C=B-1 TO B+1 @ CFLAG 1 @ IF C<1 THEN C=B
11050 IF C>LEN (Delay$) THEN 11160
11060 Temp1$="" @ Temp1$=VAL$ (C) @ Temp1$=RPT$ (" ",4-LEN (Temp1$))&Temp1$
@ OFF CURSOR @ ALPHA I2,18 @ AWRIT Temp1$
11070  Temp1$=VAL$  (NUM  (Lights$[C,C]))  @  Temp1$=RPT$  ("  ",5-LEN
(Temp1$))&Temp1$ @ ALPHA I2,24 @ AWRIT Temp1$
11080 X=VAL (Colors$[C,C]) @ IF X=0 THEN Temp1$="None" @ GOTO 11100
11090 ON X GOSUB Red ,Green ,Yellow
11100 ALPHA I2,31 @ AWRIT Temp1$&"   "
11110  Temp1$=VAL$  (NUM  (Delay$[C,C]))  @  Temp1$=RPT$  ("  ",5-LEN
(Temp1$))&Temp1$ @ ALPHA I2,39 @ AWRIT Temp1$
11120 IF Results(0,C)=0 THEN ALPHA I2,47 @ AWRIT RPT$ (" ",16) @ GOTO 11160
11130 Temp1$="" @  Temp1$[1,8]=VAL$  (Results(0,C))  @  ALPHA I2,47 @ AWRIT
Temp1$
```

```
11140 Temp1$="" @ IF Smean=0 OR Snum=0 THEN Temp1$="0" ELSE
Temp1$[1,5]=VAL$ (Smean/Snum)
11150 ALPHA I2,58 @ AWRIT Temp1$
11160 I2=I2+1 @ IF FLAG (1) THEN RETURN
11170 IF C>LEN (Lights$) THEN 11190
11180 NEXT C
11190 IF I2=6 AND (B=1 OR B=LEN (Lights$)) THEN I2=4
11200 IF I2=6 OR I2=7 THEN I2=5
11210 CFLAG 1 @ GOSUB Onlight
11211 !
12000 ! SECTION #3 ** CHANNEL SELECTION AND DATA COLLECTION
12010 ! ==========================================================
12011 !
12020 OUTPUT 717 ;"H4BJ" @ OUTPUT 718 USING "#,K" ; OUT$(B)
12030 X=TIME @ TRANSFER 717 TO Buf$ INTR ; DELIM 2 COUNT 1590
12040 GOTO 12040


12050 X1=TIME @ OUTPUT 718 ;"C" @ IF X1-X>= 5 THEN X,Results(0,B)=5 ELSE
X,Results(0,B)=X1-X
12060 IF X#5 THEN Smean=Smean+X @ Snum=Snum+1
12070 ON TIMER# 1,1000*NUM (Delay$[B,B])+5-X GOTO 12100
12080 SFLAG 1 @ C=B @ GOSUB 11050
12090 GOTO 12090
12100 OFF TIMER# 1 @ IF Stdtype$="PV" THEN GOSUB Offlight ELSE GOSUB
Multoff
12110 NEXT B
```

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